
**A Guide to Understanding Lenses and Supplementary lenses by Graham Houghton January 2023**

**Angle of View and Lenses**

In photography, angle of view (AOV) refers to the measurement in degrees of how wide the frame will be from the point of the camera. The angle of view can be measured in three planes: the horizontal angle of view, the vertical, or the diagonal. Angle of view is measured in degrees, and you can measure it with the diagonal plane of the frame. A small angle of view, measuring fewer degrees, means the frame will be tighter on the subject. A high angle of view results in a wider frame.

**The Relationship Between Focal Length and Angle of View**

The focal length of the camera lens determines the angle of view. Lenses with a long focal length and narrower angle of view, such as super telephoto lenses or zoom lenses with extreme magnification, can capture images from far away but with a tight angle of view.

Wide angle lenses and fisheye lenses have a short focal length and a wide angle of view, enabling them to capture a lot in the frame, even when the distance from the subject is very short.

Most digital camera manufacturers, such as Canon, Nikon, and Sony, list information about their lenses' focal length and angle of view in their manuals and online.

**How to Calculate Angle of View**

Angle of view is calculated by the focal length of the lens and the image sensor size within the camera, which determines the crop factor of the frame. Angle of view can be calculated using the following equation, which requires a bit of trigonometry:

Angle of View = 2 x ArcTan(sensor width/(2 x focal length))

**Angle of View (AOV) vs. Field of View (FOV): What's the Difference?**

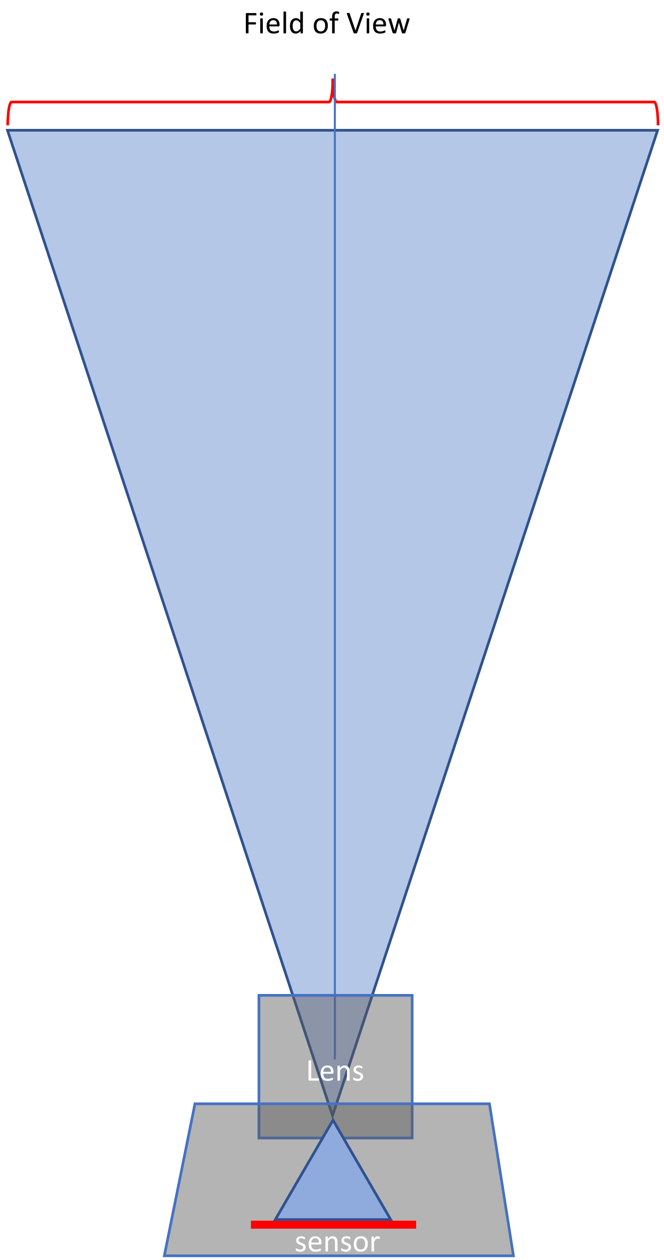
Although the terms field of view and angle of view are sometimes used interchangeably, they actually refer to different concepts: the frame dimensions and the angle at which light is allowed in, respectively. Field of view (FOV) refers to the actual dimensions of the full frame. This is typically measured as a length on the horizontal plane of the frame.

The angle of view is measured in degrees.

As well as calculating the angle of view, we can also use the same trigonometry to calculate the field of view as a linear measurement, as long as you know the distance to your subject, or, if you know the size of your subject and the focal length you are going to use, it could tell you how far away from it you need to be to get it to fill the frame.

The units of measurement will be constant in the equation, so if you use metres as your distance to subject, the linear field of view will also be in metres.

Linear field of view = 2 (Tan (Angle of view/2) X Distance to Subject)




Angle of View is an angle which depends on the focal length and sensor size, but it also computes dimensional Field of View sizes (width, height, or diagonal fields) at some specific distance, like at the subject distance, and another, like at a background distance.

*Field of View can be expressed as either the angular or dimensional field, and can be horizontal width, vertical height, or as the diagonal. Angular field of view is commonly stated as the diagonal (which is the circular lens view). The angle is independent of distance (angle is the same at any distance). Dimensional field of view (in feet, meters, etc) is computed at one specific distance (of same units). The Field of View accuracy is dependent on the accuracy of distance, focal length and sensor size dimensions.*

**Common Focal Lengths and their corresponding FOV's**

Since the equation for field of view contains the sensor width, which determines the crop factor of a sensor, this is another way to see the effect that the crop factor of a camera has on an image. The smaller the sensor, the larger the crop factor, and the smaller the field of view for a given focal length. So the Equivalent Focal Length (EFL) = Focal length x Crop Factor.

**Full Frame**

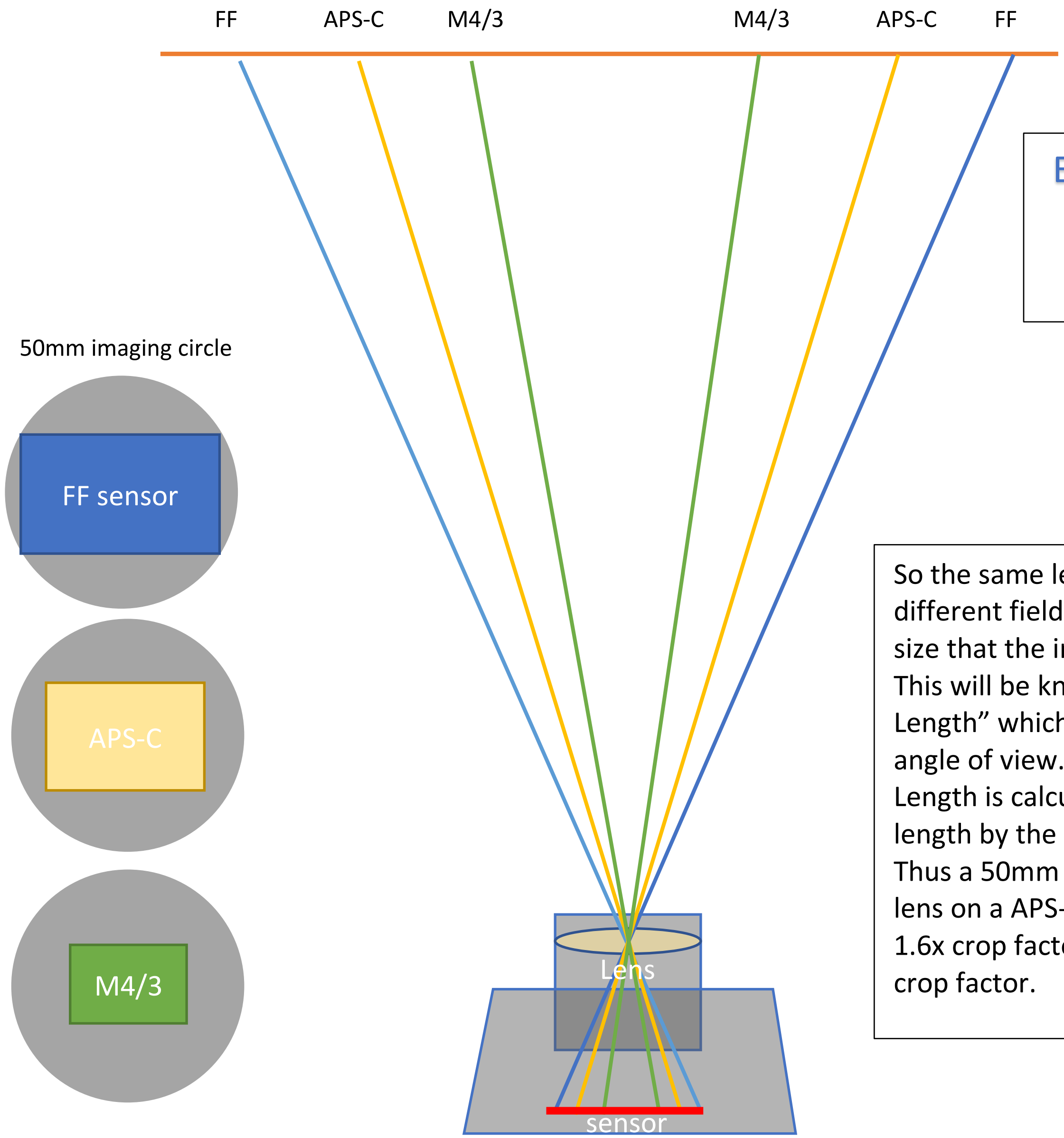
| Focal length | FOV |
|---|---|
| 16mm | 96.7 |
| 24mm | 73.7 |
| 35mm | 54.4 |
| 50mm | 39.6 |
| 85mm | 23.9 |
| 100mm | 20.4 |
| 200mm | 10.3 |
| 400mm | 5.2 |
| 600mm | 3.4 |

**APS_C (Canon)**

| Focal length | EFL | FOV |
|---|---|---|
| 16mm | 25.6mm | 70.2 |
| 24mm | 38.4mm | 50.2 |
| 35mm | 56mm | 35.6 |
| 50mm | 80mm | 25.4 |
| 85mm | 136mm | 15.1 |
| 100mm | 160mm | 12.8 |
| 200mm | 320mm | 6.4 |
| 400mm | 640mm | 3.2 |
| 600mm | 960mm | 2.1 |

**M4/3**

| Focal length | EFL | FOV |
|---|---|---|
| 14mm | 28mm | 65.5 |
| 16mm | 32mm | 58.7 |
| 24mm | 48mm | 41.1 |
| 35mm | 70mm | 28.8 |
| 50mm | 100mm | 20.4 |
| 85mm | 170mm | 12.1 |
| 100mm | 200mm | 10.3 |
| 200mm | 400mm | 5.2 |
| 400mm | 800mm | 2.6 |




# Effect on Angle of View with Sensor Size

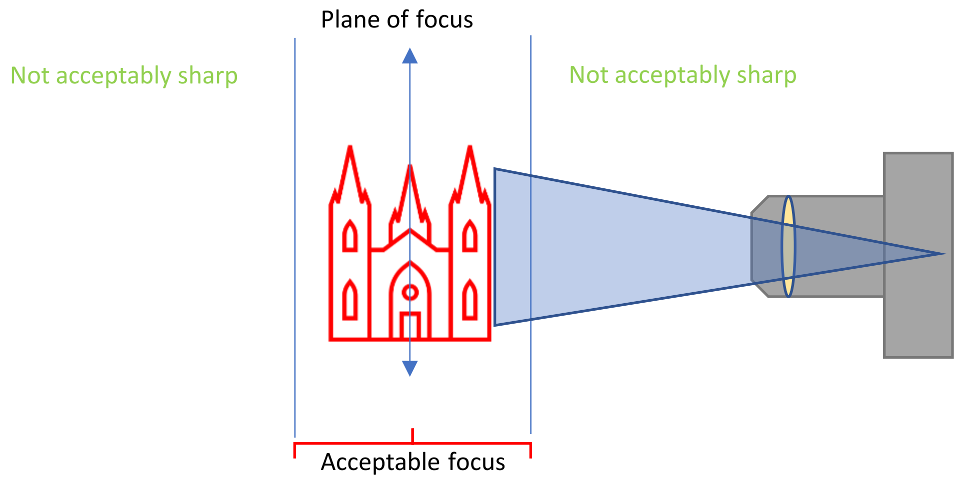
So the same lens will have different angles of view, (or different fields of view), depending upon the sensor size that the image circle is projected upon.
This will be known by the term "Equivalent Focal Length" which would be the same full frame (35mm) angle of view. In practical terms the Equivalent Focal Length is calculated by multiplying the lens focal length by the "crop factor" of the imaging sensor.
Thus a 50mm Full Frame Lens will behave like a 80mm lens on a APS-C sensor based camera,(based upon a 1.6x crop factor) and 100mm on a M4/3 sensor (2x crop factor.




The same 50mm lens mounted on a full frame camera, an APS-C camera and a Micro Four Thirds camera using the same F4 aperture showing the respective angle of view. Showing 1X, 1.6X and 2X crop factors resulting in 50mm, 80mm and 100mm Equivalent Focal Lengths.

So what happens to the "Depth of Field" when using the lens on different sensor formats?
Depth of field (DoF) is the distance between the nearest and furthest elements in a scene that appear to be "acceptably sharp" in an image.

The distance between the camera and the first element that is considered to be
acceptably sharp is called DoF near limit. Similarly, the distance between the camera and the furthest element that is considered to be acceptably sharp is called DoF far limit.
Notice that the limits of depth of field are not hard boundaries between sharp and unsharp since defocus is produced gradually.




Depth of field is not equally distributed in front (near) and behind (far) your focus point.
Usually, the far DoF is larger than the near DoF points.
For a given focal length, the nearer you focus the more evenly distributed your DoF will be (50%-50%). On the contrary, the furthest you focus the less evenly distributed.

**What affects depth of field?**

Depth of field primarily depends on the lens aperture, subject focus distance, the lens focal length and the circle of confusion (CoC). Circle of confusion depends on camera sensor size, final image size, image viewing distance and viewer's visual acuity.
Circle of confusion is a convention used to establish what we consider to be acceptably sharp in a photo.
It's the maximum diameter (mm) that a blur spot on the camera sensor will be seen as a point (in focus) in the final image or printed photo.
To produce greater DoF: use smaller apertures like (f/8-f/22), and/or shorter focal lengths (10-35mm), longer focus distances or use smaller camera sensors (crop).
Conversely to produce shallower DoF: use wider apertures like (f/1.4-f/5.6), and/or longer focal lengths (70-600mm), shorter focus distances or use cameras with larger sensors (full frame).

50mm F1.4 Lens


By moving the camera back to 2x the distance to give the same field of view using the same 50mm lens on micro four thirds the depth of field is the same when using an F-stop which is two stops bigger i.e. F4 from F8.

**Using Close-Up lenses for Photography.**

When looking at various magnifying lenses, you'll come across the term 'dioptre'. This refers to the amount of curvature a lens will have. More curvature means a thicker lens, more magnification and a higher dioptre number.
To find the magnification level of a lens, simply divide its dioptre by 4, and add 1.
For example, if you're looking at a 3-diopter lens, it's magnification = ¾ + 1… or .75 + 1 = 1.75x. Objects viewed under a 3 dioptre lens will appear 175% bigger than normal.
A 5-diopter lens = 5/4 + 1… or 1.25 + 1 = 2.25x. Objects viewed under a 5 dioptre lens will appear 225% bigger than normal.

Focal length is defined as the distance from the lens to the point where an object is in focus (focal point) and it becomes important if you need space to the object in which to focus.

If you need lots of space to capture the image, you won't have as much magnification available. If you don't need much working distance, you can get stronger magnification.
Typically close-up lenses are #1, #2 and #4 dioptres although some sets include a #10 but these are rarely good quality as distortion in a single lens is very high.
To overcome the distortion and colour fringes "Achromatic" lenses are produced. The best known of these is probably the "Raynox Brand"

#1 dioptre = 1.0x magnification at 39 inches focal length
#2 dioptre = 1.5x magnification at 19 inches focal length
#3 dioptre = 1.75x magnification at 13inches focal length
#4 dioptre = 2.0x magnification at 9.5 inches focal length
#5 dioptre = 2.25x magnification at 8 inches focal length
#10 dioptre = 3.5x magnification at 5.5inches focal length


The simplest, and least expensive, way to make a lens focus closer is to add a supplementary lens to it. Supplementary lenses—which are also known as close-up lenses, dioptre lenses, and plus lenses—are thin lenses that look just like filters and usually screw onto the front of a lens just like any other filters do. They are available in standard filter sizes such as 52mm, 58mm, or 62mm in diameter. Attaching a supplementary to a lens, whether a fixed-focal-length or a zoom, allows the lens to focus in the close-up range.
The actual working distance you have and the subject coverage you end up with, that is, the magnification achieved, depends on the power of the dioptre you're using; the focal length of the lens that you are adding it to and the close focussing ability of the lens itself.

Supplementary dioptres work by reducing the effective local length of the lens on which they are used. Here is a formula for determining the actual focal length at which you end up: 1 / (1/lens focal length + dioptre strength)

To check this out here's some examples so that you can see what happens to focal length.
Method: calculate the lens dioptre, add the supplementary lens and then find the reciprocal

Assume that you're using a #3 dioptre. Add it to a 24mm lens and you end up with an effective 22.4mm lens.
Which is an effective lens dioptre of 1/0.024 = 41.67.
Now add the supplementary dioptre 41.67 + 3 = 44.67. Now the reciprocal gives the new focal length and so 1/44.67 gives 0.0224metres or 23mm

Place the same #3 dioptre on a 50mm and you get a 43.5mm lens. This would give 1 / ((1/0.050) + 3)
Which is 1 / (20 + 3) or 1/23 which is 43.5mm.

Mount that #3 dioptre on a 100mm lens and you have a 77mm lens focal length.

Again the new focal length is 1 / ((1/100) +3) which is 1 / ((1/0.100) +3) or 1 / (10 + 3) or 1/13 = 77mm

Adding a dioptre to a short focal length doesn't alter the focal length much since the more the effective focal length changes, the more the image size changes.

All closeup dioptres make whatever lenses they are added to focus at the same working distance if these prime lenses are set to the same focusing distance. In other words, if you set a 50mm, a 100mm, and a 200mm lens at infinity focus and add a +3 dioptre to each, they will all focus at the exact same working distance.
At infinity focus on the prime lens, the working distance of any lens will be roughly 1 metre divided by the dioptre power of the supplementary lens.
Therefore, a #1 dioptre will make a lens focus at 1 metre; a #2 dioptre gives a focus distance of 0.5 metre, or about 19 1/2 inches; and a #3 dioptre yields 0.3 metre or just over 13 inches.
Of course you can still use the focusing ring of the lens to gain some more magnification.

We now come to an important concept. If all lenses will be in focus at the same working distance, it follows that the longer the prime focal length is the more magnification you'll get. The longer the lens you use a dioptre on, the greater the magnification achieved.

But there's a catch; almost all the common single-element closeup dioptres made are optically designed for use with a 50mm ("normal") lens.
This is a focal length you rarely want to use for nature closeup photography because it doesn't allow for enough working distance between the lens and your subject.

Adding the dioptre only compounds the problem, as it leaves you with a lens that is effectively even shorter.
But if you put that standard single-element #3 dioptre on a 200mm in order to gain working distance, you'll definitely have sharpness.

The actual magnification you obtain at the sensor with infinity focus can also be computed with a formula.

Magnification = focal length of camera lens / focal length of close-up lens

A #3 dioptre has a focal length of 333mm (1,000mm / 3).

When this is used on a 50mm lens it gives 50mm / 333mm or about 0.15X.
Add it to a 100mm lens instead and you have 100mm / 333mm or 1/3X.
Put in on a 200mm lens, and now you get 200mm / 333mm or 0.6X magnification.

Besides loss of image quality, the big problem with using dioptres in the field goes back to the earlier problem of taking close-ups with short-focal-length lenses. Remember that most dioptres are optimized for use on a 50mm lens.
To achieve the same image size—the same magnification that is—using two different lenses, you need a stronger dioptre on the shorter-focal-length lens than on the longer lens.

Let's look at a few figures. To achieve 1/2X, a subject area of 2x3 inches, you need a +10 dioptre on a 50mm lens, but only a +2.5 dioptre on a 200mm. But... and here's that catch again ... look what happens when you add a +10 to the 50mm.

It becomes an effective 33.3mm lens with all the problems of a short focal length lor closeups: lack of working distance and wider background coverage.

**How can I calculate its effect on close focusing distance?**

Roughly speaking the close focusing distance will be reduced according to:

new distance = old distance / ( (D x  old distance) + 1) ,

*where*
new distance is the close-focusing distance with the close-up lens applied;
old distance is the original close-focusing distance (without the close-up lens);
D is the dioptre of the close-up lens.

For example, suppose a lens can focus as closely as 500mm. With a +4 dioptre close-up lens attached, the combination can now focus as close as 500 mm / ((4m x 0.5m) + 1) which is (500/3)mm ≈ 167mm.
This formula is an approximation as it doesn't take into consideration compound lenses, lens thickness and the camera's minimum focus distance.


A series of close-up lenses #1, #2 and #4